SciComp, Inc.

Automatic Synthesis of Computer Code for Mathematical Modeling

To effectively analyze systems such as traffic management, electrical or mechanical implementations, weather prediction, or economic or financial models, researchers need tools to gain a better understanding of these complex systems. A very popular tool for system analysis is software modeling. Mathematical software modeling methods, which gained popularity in the mid-1990s, are widely used, especially in creating complex financial models. During that time, one of the firms championing this method was SciComp, Inc. a software development firm in Austin, TX. SciComp proposed to develop new technology that would eliminate the programming task for modelers by automatically synthesizing computer code from high-level specifications. The synthesized code would be in the form of a component, which could then be reused in many different applications. To develop the new technology, SciComp needed financial assistance. In 1994, the company received an award from the Advanced Technology Program's (ATP) focused program, "Component-Based Software," for a three-year project that would begin in January 1995.

By the end of the project in 1998, SciComp had successfully developed a software synthesis technology for creating mathematical models that not only made modeling simpler, more accurate, and less expensive, but also immensely shortened the creation effort. Since then, the company has incorporated this technology into SciFinance, a family of financial software products used by the derivative securities industry. In 2004, the company anticipated revenue of approximately $1.5 million from the sale of these products. The ATP-funded project also resulted in two patents and several publications and presentations.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 94-06-0003 were collected during March – May 2004.

Mathematical Modeling Is Used across Many Industries

By the mid-1990s, mathematical modeling for computer simulation was increasingly being used by organizations to optimize many scientific applications. For example, it was being used to improve the efficiency of power, refrigeration, and cooling systems. It was also being used in computational fluid dynamics to refine automobile, ship, and aircraft designs quickly, efficiently, and inexpensively and in calculations to enhance engine and turbine efficiency. However, other software modeling methods, which were different from these well-known three-dimensional object-modeling methods, began to gain in popularity during this time.

Partial differential equation pricing models, one form of these new systems analysis tools, were being used by financial institutions. As these institutions entered the arena of complex financial derivatives (hedging contracts), highly paid quantitative analysts known as "quants" programmed, by hand, complex partial differential equation pricing models into computers. While these pricing models were effective, they could take a week or more to program, delaying the ability of derivative traders to do their business as quickly as customers wanted. Since the quants were so highly paid, each derivative model was costly to program.

As the derivative market continued to grow, investment banks, brokerage firms, insurance companies, and

hedge funds increasingly utilized pricing models for complex derivative structures. Because of this increase, these institutions began to seek technology that would assist them in quickly and accurately producing simulation tools to price financial instruments such as futures and options.

New Technology Could Eliminate Programming

SciComp Inc., a start-up firm in Austin, TX, sought to reduce the costs of code development and maintenance. The company proposed to accomplish this by developing software synthesis technology that would eliminate the programming task and create a validated, reusable, interoperable software component. Based on SciComp's existing prototype, researchers had to specify in a computer language only high-level considerations, such as an equation they were trying to solve or variables and domains for which they needed solutions. The required code to solve the mathematical modeling problem would then be automatically generated. This resultant component would be a block of code that could be accessed and used for many applications.

SciComp anticipated that the newly created interoperable software components would significantly increase the productivity of mathematical modelers. In addition, they would be able to quickly validate code without the tedious, time-consuming task of programming. This would give quants more time to experiment with complex models and to find high-quality solutions to application problems. Automatically generated components would also result in more reliable models, because there would be fewer errors in the code. Furthermore, these interoperable components would provide new options for developing a greater variety of models by enabling modelers to combine components in new ways.

SciComp Focuses on the Financial Markets

Initially, SciComp planned to apply its new software development technology in many areas, such as groundwater modeling for environmental cleanup and safe waste storage and air pollution monitoring. However, the company quickly determined that, due to the enormous task of rewriting a customer's outdated code, their efforts would quickly outweigh any revenue gained. So, SciComp turned its attention to financial areas. One possible application was using partial differential equations to price and value derivative securities. In the early 1990s, the derivative market was quickly growing. SciComp anticipated that, as the market continued to expand, investment banks, brokerage firms, insurance companies, and hedge funds would increasingly turn to automated software algorithms to price complex derivative structures faster and more efficiently.

Software Synthesis Technology Poses High Risk

SciComp's scientific computing goals for the financial industry contained many shortfalls prior to completion. The company did have a proof-of-concept system, SciNapse, which had already demonstrated the basic characteristics of the new technology. However, in order to extend SciNapse, SciComp would have to develop a fundamental specification language that could express a sufficiently general class of problems and solutions while still using specific algorithms. In addition to striking this difficult balance, the company would have to generate intuitive user interfaces for existing numerical and visualization libraries (sets of ready-made software routines) so that the user could quickly find appropriate solutions to standard mathematical modeling problems.

Institutions began to seek technology that would assist them in quickly and accurately producing simulation tools to price financial instruments.

To further develop the SciNapse system, SciComp approached venture capitalists and private firms for additional funding, but found they were unwilling to fund a project that sought to produce a product with no commercial antecedent. In 1994, SciComp finally submitted a proposal to ATP's focused program, "Component-Based Software" and received a three-year award, which began in 1995.

SciComp Successfully Develops Software Synthesis Technology

SciComp's goal was to streamline the mathematical modeling process and increase the productivity of modelers by developing automated technology that

would eliminate the programming task. To achieve this goal, the company would have to meet several technical objectives; these key objectives and SciComp's results are summarized below.

- *Develop intuitive software languages for nonexperts*. **Result:** SciComp redeveloped the specification language used by SciNapse, which significantly increased the language's ease of use. For example, several graduate students were able to learn to write specifications in less than a day. In the past, coding efforts took days, if not weeks.

- *Enable the specification of software performance characteristics as well as the selection of algorithms and components to fit the specifications*. **Result:** By the end of the project, SciComp had developed a technique to extend the algorithms within the specification language to describe desired performance characteristics, such as time (the time it should take for an operation to complete) and space (the amount of computer memory to be used by the algorithm). SciComp also devised ways to select components to meet the modeler's specifications.

- *Make the generated code easily customizable by preserving a record of the original assumptions and design decisions*. **Result:** By the end of the project, the code contained documentation and provided consistency in modeling assumptions. These successes gave future programmers the ability to understand underlying logical premises so that code could be easily modified if necessary.

- *Increase the speed of automating modeling programs (no more than three minutes per page of target code)*. **Result:** By the end of the project, generating code on a state-of-the-art personal computer averaged two minutes per page (one minute per page for simpler codes and three minutes per page for more complex codes).

- *Increase the modelers' productivity by a factor of at least 10*. **Result:** It was difficult to measure increases in modeler productivity, because assessments were made in a noncommercial environment. However, SciComp received several comments from users regarding gains in productivity. For example, a business school graduate student with minimal programming skills was able to price a complex correlation option in only a few hours using the new technology. In contrast, previously an experienced programmer would have taken approximately a week to manually produce the code required to price the same option.

Focus Turns to Derivative Securities Industry

During the ATP-funded project, SciComp formulated a plan to commercialize approximately 10 applications of its automated mathematical modeling software tool. To develop the plan, the company contracted with a market research firm to conduct a market survey. Based on the results of the survey, SciComp decided to focus its initial commercialization efforts on the financial software market, specifically the derivative securities industry. This industry depends on mathematically complex pricing programs utilizing partial differential equations, which are written by highly paid quantitative analysts. With SciComp's planned software products, analysts would be relieved of the difficult and time-consuming programming involved in developing custom financial instruments.

As SciComp's ATP-funded project came to a close in 1998, the financial software market was rapidly growing, with industry-wide revenue of $200 million per year amid annual increases of 37 percent. SciComp's potential customers were accustomed to spending between $100,000 and $5 million on software purchases. In contrast, SciComp anticipated that its software products would cost between $200,000 and $500,000 per site as the maturing industry became more competitive.

SciComp Develops New Financial Software System

In 1998, shortly after the ATP-funded project ended, SciComp began to incorporate its new technology into a financial software system called SciFinance that could be used to automate the pricing of complex derivative securities. The system included the following tools:

- SciPDE (originally called SciFinance), which could be used to automate the solution of sets of partial differential equations

- SciMC (utilizing Monte Carlo or random probability methods), an alternative technique for solving systems of stochastic (random) equations, which

allowed more dimensions (Dimensions are variables in a situation. For example, time, product type and region are three dimensions of a sales situation.)

- SciValidator (originally called SciRisk), which could be used to restructure derivative portfolios for greater risk and adjusted profits

The software system also included SciNapse, the underlying technology for the SciComp products. SciComp anticipated that these software tools would significantly reduce the time it took to price complex derivative securities and would increase the accuracy of the pricing. The tools could also be used in organizing libraries of modeling software components for derivatives pricing and provide highly developed risk-management analyses.

Interoperable software components would significantly increase the productivity of mathematical modelers.

SciComp planned to sell its products through marketing partnerships, direct sales, and licensing agreements. The company's target customers were quants, financial engineers, traders, risk managers, money managers, and corporate treasurers. By the end of the ATP-funded project, SciComp had established contacts with more than 50 prospects and had identified an additional 2,000.

New Financial Software Is Successfully Commercialized

By April 1998, three months after the ATP-funded project ended, SciComp's software solution, now called SciFinance, was being evaluated at four investment banks, including Chase Manhattan Bank and J.P. Morgan, the largest and second-largest U.S. derivative traders, respectively, and at Union Bank of Switzerland, the third largest derivative trader worldwide. A research laboratory, a university, and three consulting firms were also evaluating the software. In addition to the SciFinance products, SciComp offered its customers consulting services such as custom programming, installation, and support services.

By 1999, SciComp had nine customers in the financial industry, including Merrill Lynch and Bear Stearns. That year, SciComp sold seven one-year licenses for SciFinance. The company also received additional funding of $1.5 million for research and development (R&D) from a venture capital fund. By 2001, SciComp's annual revenue had reached approximately $1 million; however, the company still had not earned enough to recoup all of the costs associated with R&D and product commercialization. But SciComp was optimistic that its revenue would continue to increase.

Shortly thereafter, a series of events occurred that significantly affected the U.S. financial marketplace. The terrorist attacks on September 11, 2001 were followed by numerous corporate fraud cases and a decline in the technology sector. As a result, demand for SciComp's software products fell.

Since 2001, SciComp has continued to develop its products and, as of 2004, the company has five financial software products in its SciFinance solution. In addition to SciPDE, SciMC, and SciValidator, which incorporate the ATP-funded synthesis technology, SciFinance includes the following two products that enhance SciPDE and SciMC:

- SciXL, software for creating custom Excel spreadsheets for mathematical models

- SciIntegrator, software for integrating pricing and hedging models into trading and risk management systems, web sites, and applications with .Com, Java, or .Net wrappers

In 2004, the financial market began to recover, and the volume of derivative securities trading continued to grow, resulting in increased demand for software tools to assist in the pricing of complex derivative structures. Furthermore, there are no direct competitors to the suite of products that SciComp has developed. Because of its automation, the SciComp products are unique within the financial services sector.

SciComp has also increased its sales and marketing efforts by forming several joint venture relationships, including one with CANdiensten, an educational organization and distributor of Mathematica in Europe. SciComp also advertises on the web through

Google.com and in publications such as Wilmott, a magazine for quantitative analysts. The company currently has numerous distributors and support staff locations, including New York, London, Amsterdam, and Australia. In 2004, the company anticipated revenues of $1 million to $1.5 million from sales of SciFinance.

Through its strategic alliances, SciComp plans to continue its development of software tools that incorporate the ATP-funded technology. For example, the company has formed an alliance with the TAF Corporation. SciComp's solutions for rapidly developing and implementing derivatives pricing models now include TAF's PARAGON-enabled product to rapidly accelerate the speed of calculations. In the future, the company would like to explore new applications of its technology, such as in the evaluation and design of other commercial systems including antennas, cell phones, and drug design and delivery.

Conclusion

With ATP's assistance, SciComp successfully developed software synthesis technology that simplifies the mathematical modeling process for financial industry experts by eliminating the programming task and by substantially adding to increases in modeling productivity. Modelers can now quickly generate validated code for models without having to perform the repetitive, time-consuming task of programming. As a result, they now have more time to develop experimental models and find solutions to difficult application problems. With an automated process, models are also more accurate and can be generated at less cost.

Since 1998, SciComp has incorporated its new ATP-funded technology into SciFinance, a family of software products for the derivative securities industry. These products can be used to develop different types of software, without manual programming, for many complex functions, including pricing derivative securities, organizing libraries of derivative pricing, and providing risk-management analyses. By 2001, SciComp's cumulative revenue from sales of these products had reached $2 million; however, due to the terrorist events that year, which significantly affected the financial industry, sales declined. In 2004, the company experienced increased demand for its financial software products as the market recovers and the company strengthens its marketing efforts. SciComp anticipates 2004 revenues of approximately $1.5 million from sales of these products.

As a result of the ATP-funded project, SciComp was granted two patents, published several papers, and gave presentations on its research.

PROJECT HIGHLIGHTS
SciComp, Inc.

Project Title: Automatic Synthesis of Computer Code for Mathematical Modeling (Automatic Generation of Mathematical Modeling Components)

Project: To develop component software and automated software composition technologies for the field of scientific computing.

Duration: 1/15/1995–1/14/1998
ATP Number: 94-06-0003

Funding (in thousands):

ATP Final Cost	$1,904	87%
Participant Final Cost	282	13%
Total	$2,186	

Accomplishments: With ATP funding, SciComp, Inc. developed component software and a software synthesis technology for creating mathematical models in the field of scientific computing.

SciComp, Inc. also received the following patents for the technology related to the ATP-funded project:

- "System and method for financial instrument modeling and valuation"
  (No. 6,173,276: filed August 21, 1997; granted January 19, 2001)

- "System and method for financial instrument modeling and using Monte Carlo simulation"
  (No. 6,772,136: filed January 3, 2001; granted August 3, 2004)

Commercialization Status: Since 1998, SciComp has incorporated its new technology into SciFinance, a software solution for the derivative securities industry. This system of products includes tools that can be used to automate the pricing of complex derivative securities, organize libraries of pricing codes, and provide risk-management analysis.

In 2001, SciComp's revenue from sales of SciFinance reached $2 million; however, due to the severe social and economic setbacks that year, sales were weak in the year following. As of 2004, SciComp offered three software tools in the SciFinance solution that incorporate the ATP-funded software synthesis technology; SciFinance also includes two additional products that enhance SciPDE and SciMC. SciComp experienced greater demand for these products as the market recovered and as the company increased its marketing initiatives. As of 2004, SciComp anticipates revenue of approximately $1.5 million.

Outlook: The outlook is positive for continued demand for SciComp's financial software tools. Since 1990, the volume of derivative securities trading has steadily increased. In 2000, it reached more than $80 trillion. As the derivative market continues to grow, investment banks, brokerage firms, insurance companies, and hedge funds will utilize pricing models for complex derivative structures and are likely to seek tools that will assist them in quickly and accurately producing simulation tools for these models. In 2004, SciComp had few competitors that provided these software products.

Composite Performance Score: * * * *

Focused Program: Component-Based Software, 1994

Number of Employees: 1 employee at project start, 5 as of November 2004

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Publications:

SciComp published its findings in the following:

- Randall, C., E. Kant, and S. Kostek. "Automatic Synthesis of Financial Modeling Codes," *Proceedings of the International Association of Financial Engineers First Annual Computational Finance Conference*, Stanford, CA, August 23-24, 1996.

- Akers, R., E. Kant, C. Randall, S. Steinberg, and R. Young. "SciNapse: A Problem-Solving Environment for Partial Differential Equations," *IEEE Computational Science and Engineering*, 4:3, 32-42, 1997.

- Randall, C. and E. Kant. "Numerical Options Models Without Programming," *Proceedings of the IEEE/IAFE Conference on Computational Intelligence for Financial Engineering*, New York, NY, March 23-25, 1997.

PROJECT HIGHLIGHTS
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- Kant, E. and S. Steinberg. “Automatic Program Synthesis from Abstract PDE Specifications,” *Proceedings of the 15th IMACS World Congress on Scientific Computation, Modeling, and Applied Mathematics*, Berlin, Germany, August 24-29, 1997.
- Randall, C., E. Kant, and A. Chhabra. “Using Program Synthesis to Price Derivatives,” *Journal of Computational Finance*, 1:2, 97-128, 1998.
- Brown, G.W. and C. Randall. “If the Skew Fits,” *Risk Magazine*, 12:4, 62-65, 1999.
- Gatheral, J., Y. Epelbaum, H. Jining, K. Laud, O. Lubovitsky, E. Kant, and C. Randall. “Implementing Option-Pricing Models Using Software Synthesis,” *Computing in Science & Engineering*, 1:6, 54-64, 1999.
- Akers, R., I. Bica, E. Kant, C. Randall, and R. Young. “SciFinance: A Program Synthesis Tool for Financial Modeling,” *AI Magazine*, 22:2, 27-41, 2001.
- Akers, R., P. Baffes, E. Kant, C. Randall, S. Steinberg, and R. Young. “Automatic Synthesis of Numerical Codes for Solving Partial Differential Equations,” *Special Issue on Non-Standard Applications of Computer Algebra, Mathematics and Computers in Simulation*, Elsevier Science Publishers, North-Holland (to be published).

Presentations:

SciComp also disseminated knowledge gained during the project through the following presentations:

- Kant, E. and S. Steinberg. “Automatic Program Synthesis from Abstract PDE Specifications,” The 15th IMACS World Congress on Scientific Computation, Modeling, and Applied Mathematics, Berlin, Germany, August 24-29, 1997.
- Randall, C. and E. Kant. “Numerical Options Models Without Programming,” The IEEE/IAFE Conference on Computational Intelligence for Financial Engineering, New York, NY, March 23-25, 1997.
- Randall, C., E. Kant, and S. Kostek. “Automatic Synthesis of Financial Modeling Codes,” The International Association of Financial Engineers First Annual Computational Finance Conference, Stanford, CA, August 23-24, 1996.